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**Fan et al.**

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(54) **METHOD AND SYSTEM FOR ADAPTIVELY SCANNING A SAMPLE DURING ELECTRON BEAM INSPECTION**

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(51) **Int. Cl.**

| | |
|---|---|
| ***H01J 37/28*** | (2006.01) |
| ***H01J 37/21*** | (2006.01) |
| ***G01N 23/225*** | (2006.01) |
| ***H01J 37/147*** | (2006.01) |

(52) **U.S. Cl.**
CPC ............ ***H01J 37/28*** (2013.01); ***G01N 23/2251*** (2013.01); ***H01J 37/147*** (2013.01); *H01J 2237/24592* (2013.01); *H01J 2237/2817* (2013.01)

(58) **Field of Classification Search**
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USPC ............. 250/310, 307, 311, 306, 396 R, 397, 250/398, 252.1, 370.08, 491.1
See application file for complete search history.

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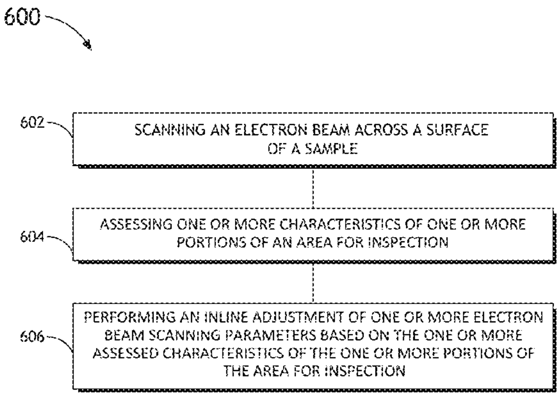
(74) *Attorney, Agent, or Firm* — Suiter Swantz pc llo

(57) **ABSTRACT**

A system for adaptive electron beam scanning may include an inspection sub-system configured to scan an electron beam across the surface of a sample. The inspection sub-system may include an electron beam source, a sample stage, a set of electron-optic elements, a detector assembly and a controller communicatively coupled to one or more portions of the inspection sub-system. The controller may assess one or more characteristics of one or more portions of an area of the sample for inspection and, responsive to the assessed one or more characteristics, adjust one or more scan parameters of the inspection sub-system.

**34 Claims, 11 Drawing Sheets**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602
SCANNING AN ELECTRON BEAM ACROSS A SURFACE OF A SAMPLE
604
ASSESSING ONE OR MORE CHARACTERISTICS OF ONE OR MORE PORTIONS OF AN AREA FOR INSPECTION
606
PERFORMING AN INLINE ADJUSTMENT OF ONE OR MORE ELECTRON BEAM SCANNING PARAMETERS BASED ON THE ONE OR MORE ASSESSED CHARACTERISTICS OF THE ONE OR MORE PORTIONS OF THE AREA FOR INSPECTION

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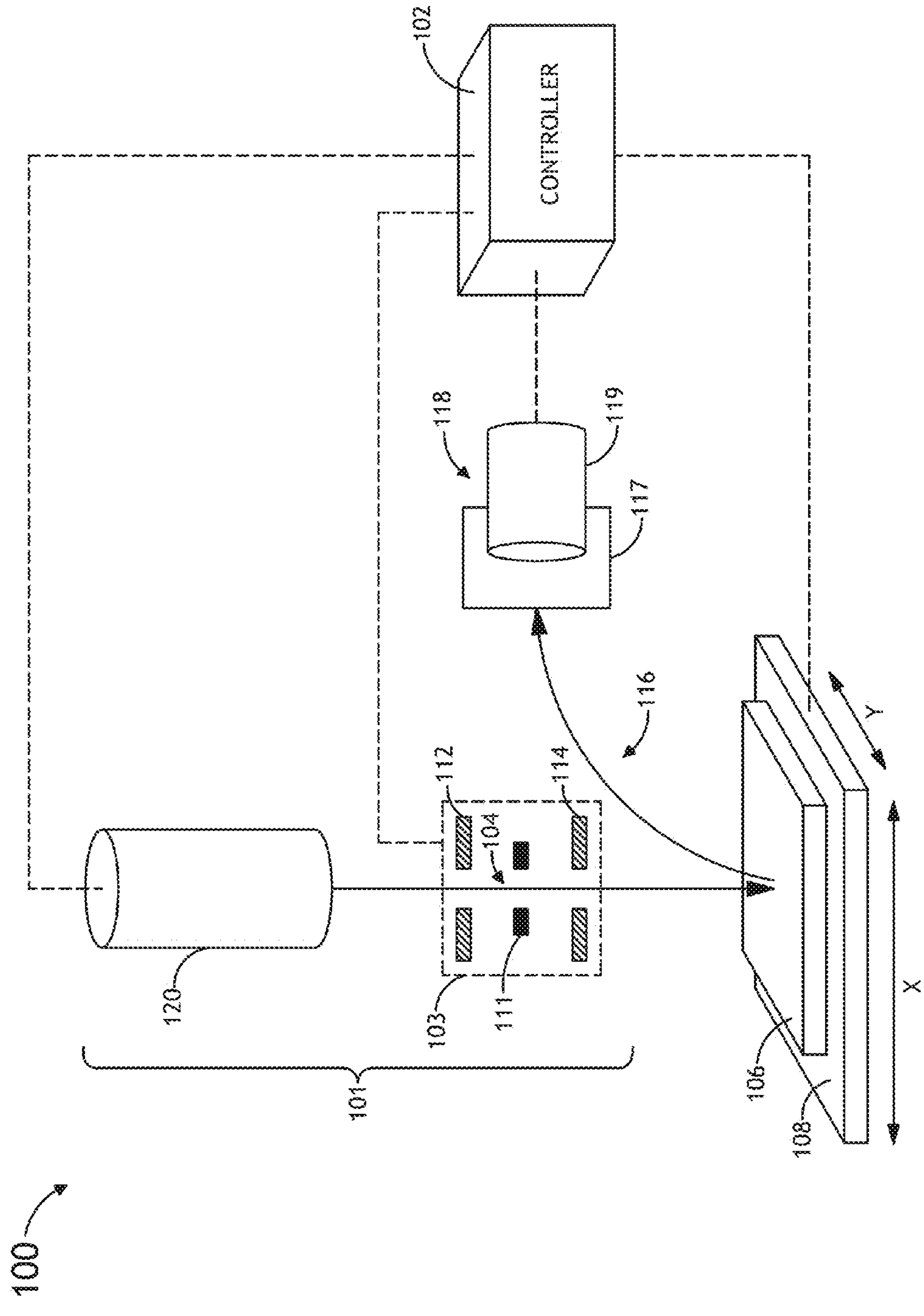
CONTROLLER
X
Y

FIG. 1

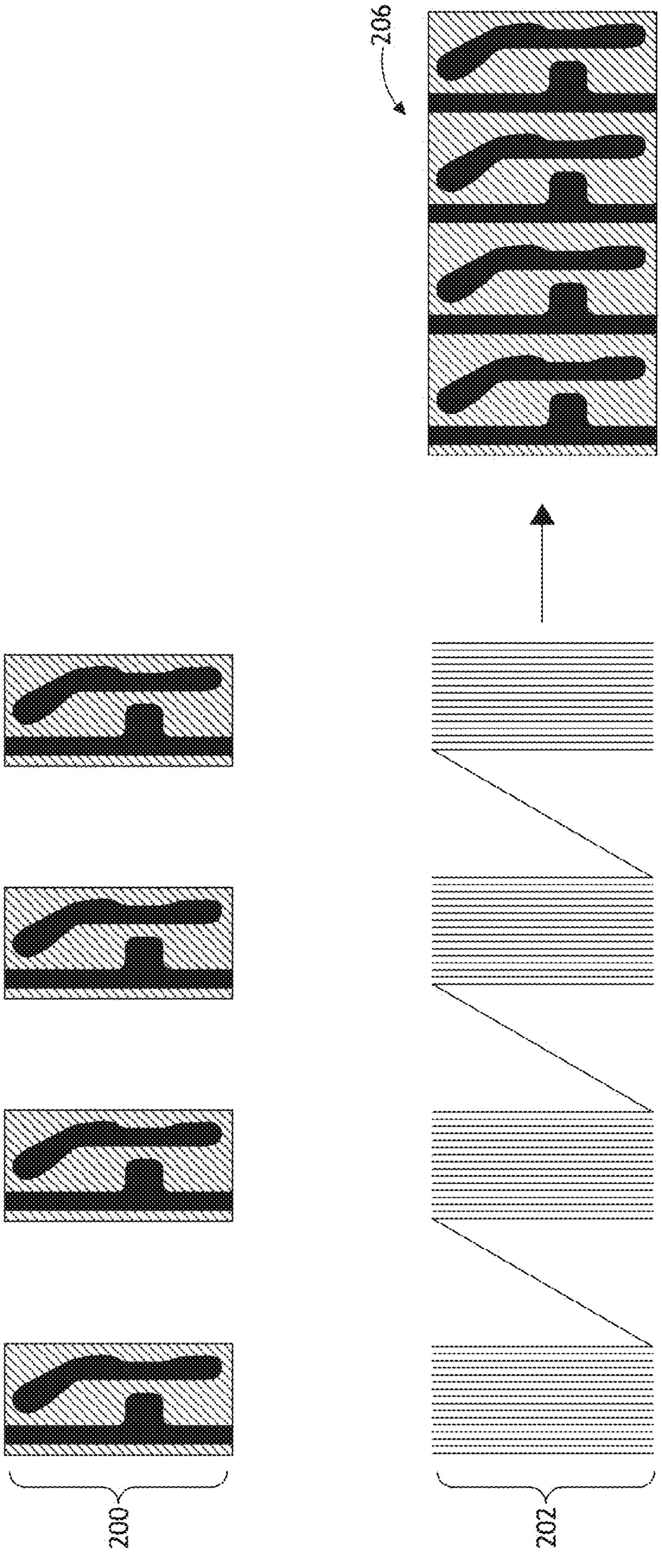

FIG.2A

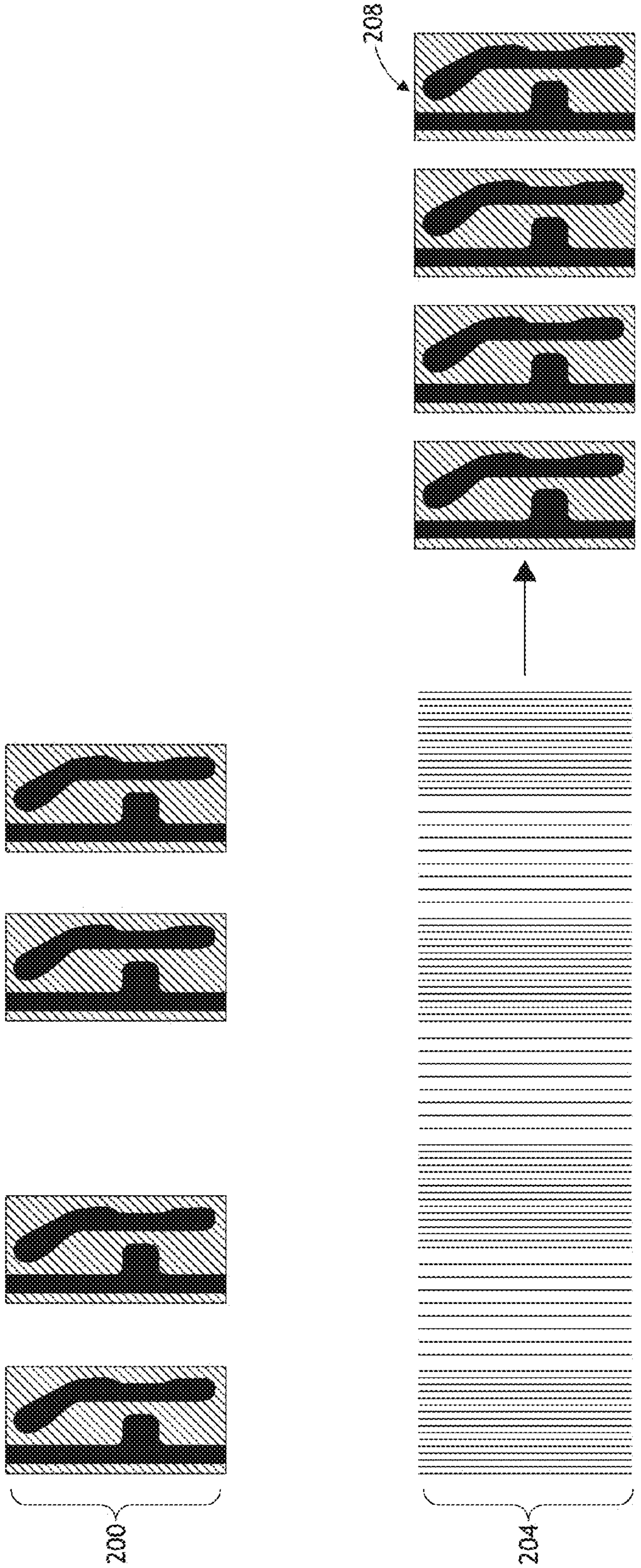

FIG. 2B

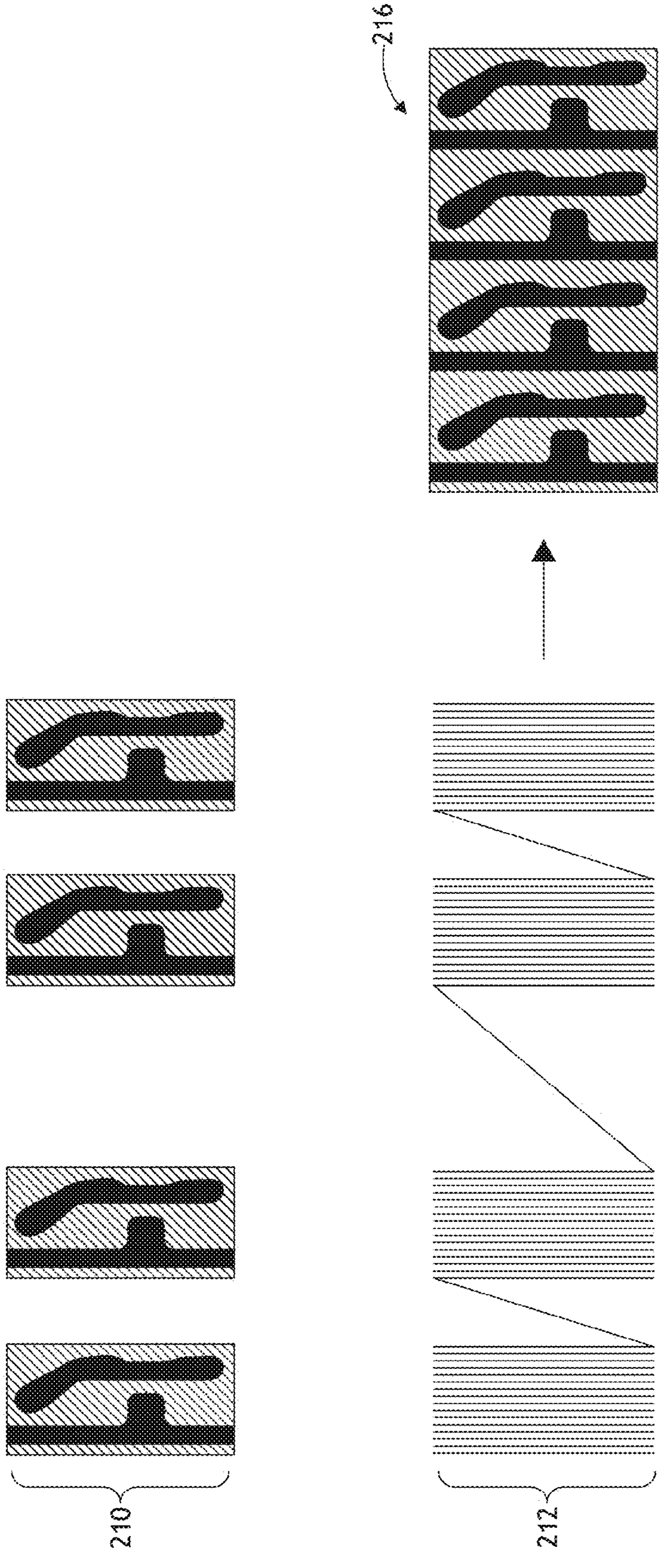

FIG. 2C

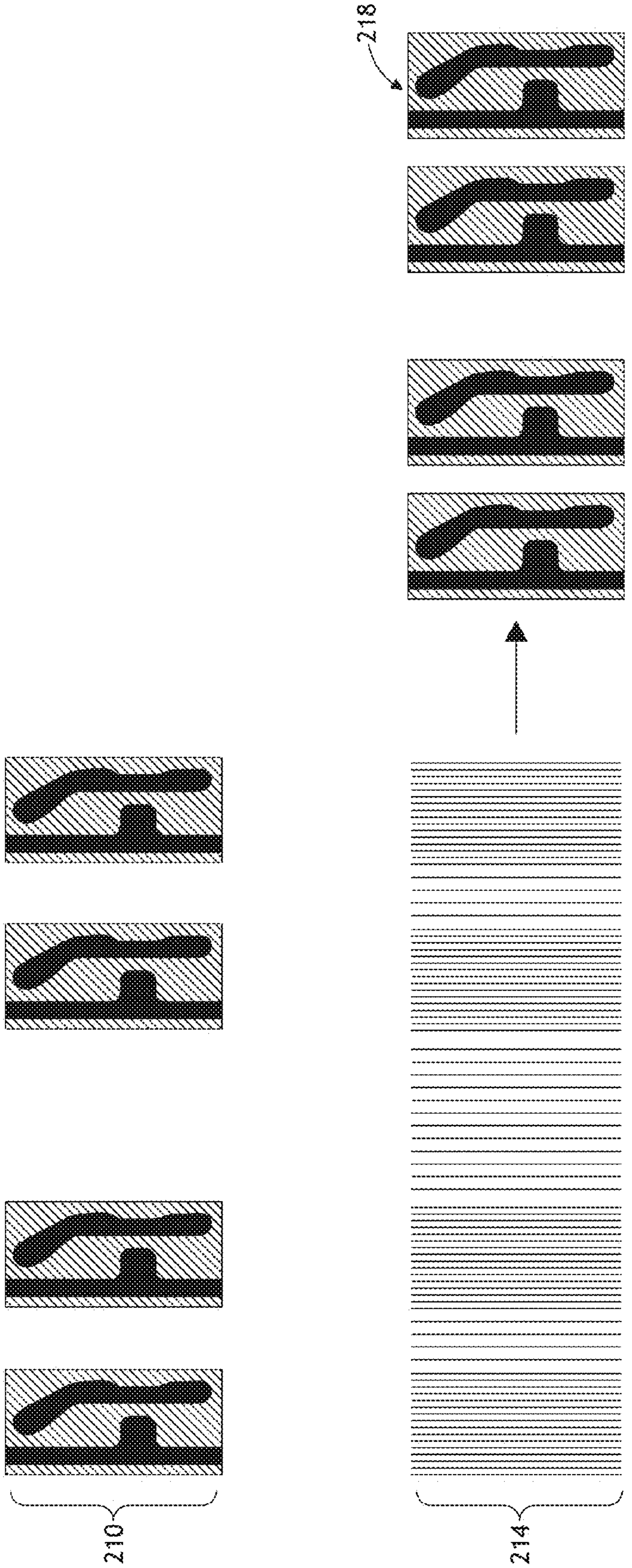

FIG. 2D

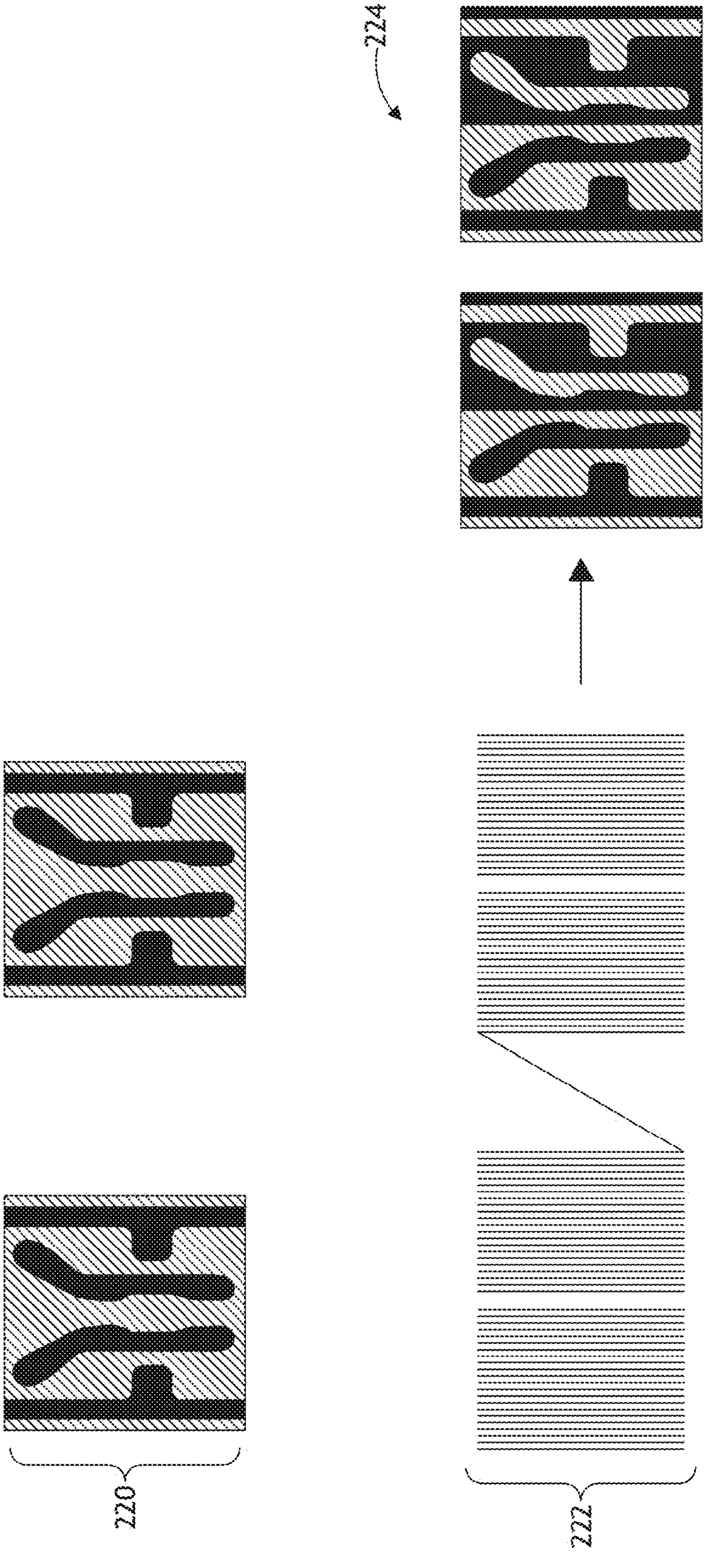

FIG. 2E

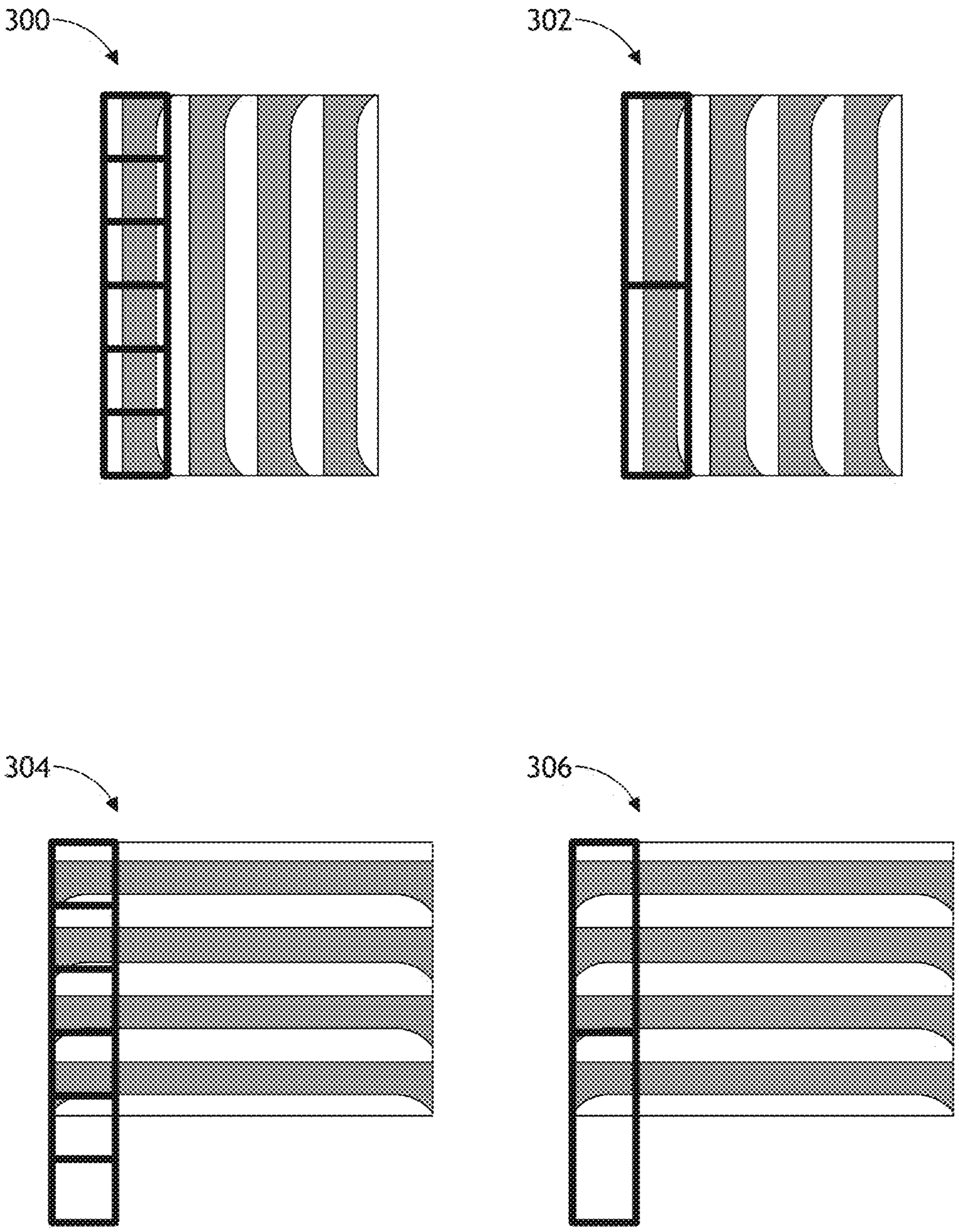
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FIG.3A

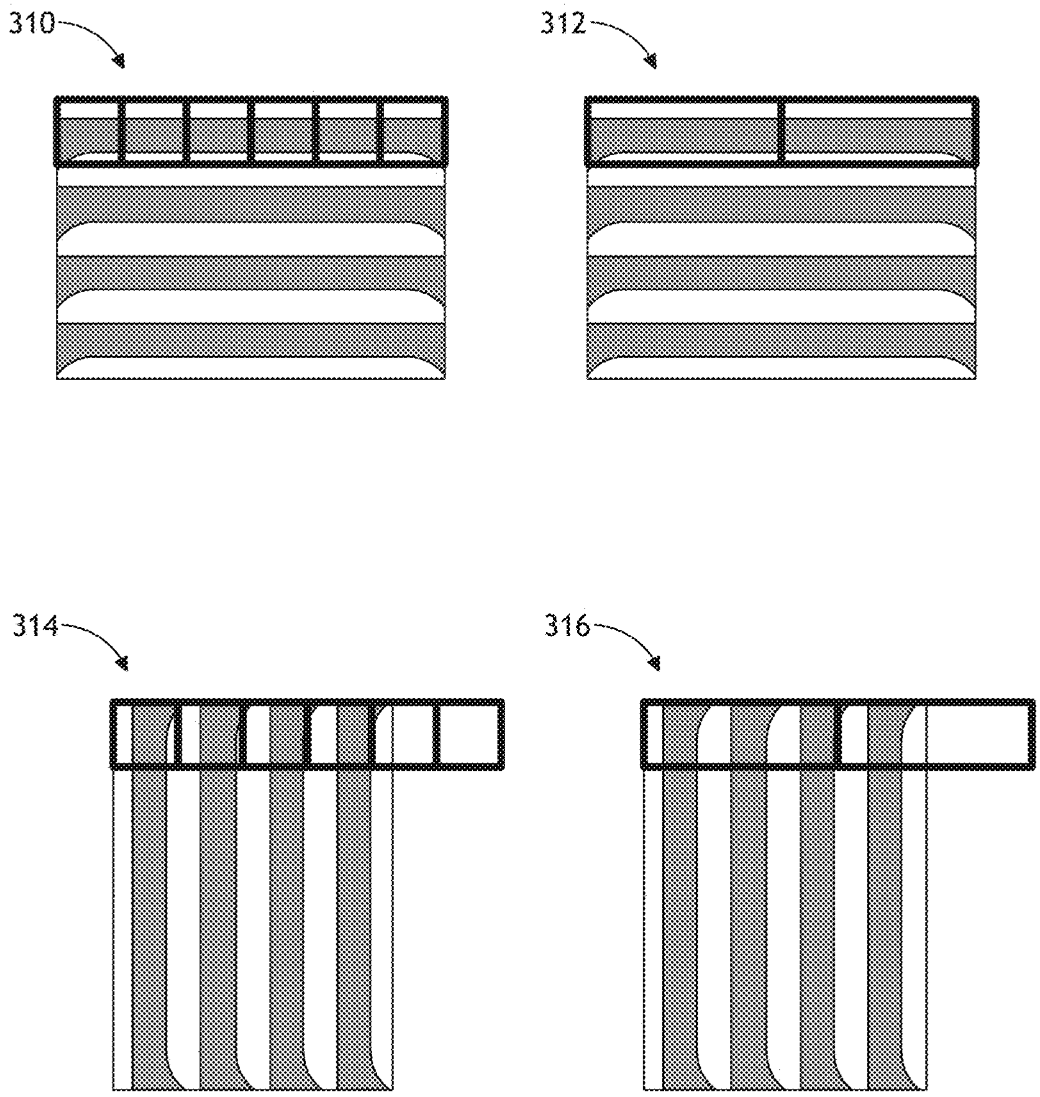
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FIG. 3B

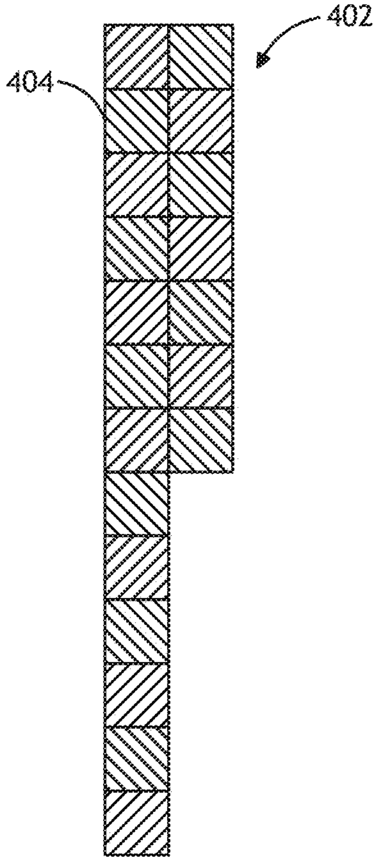

FIG. 4A

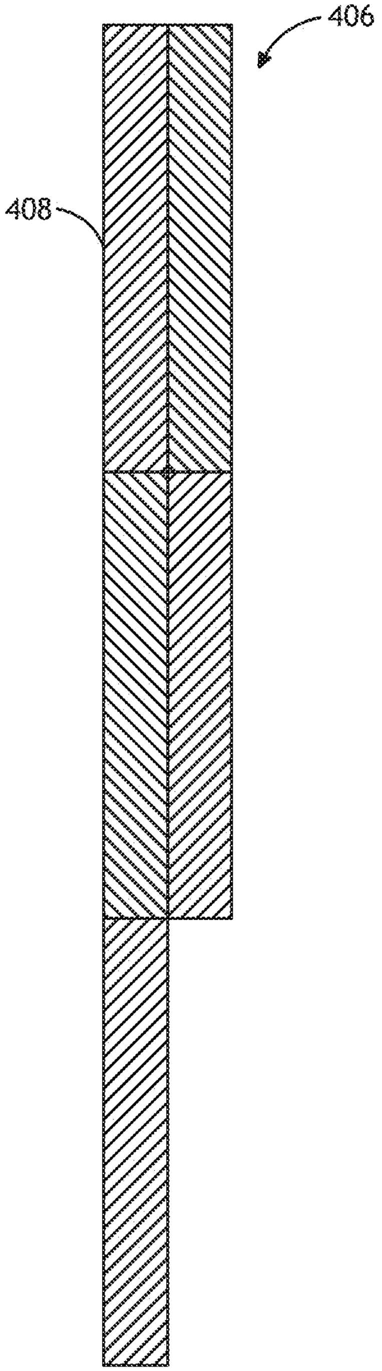

FIG. 4B

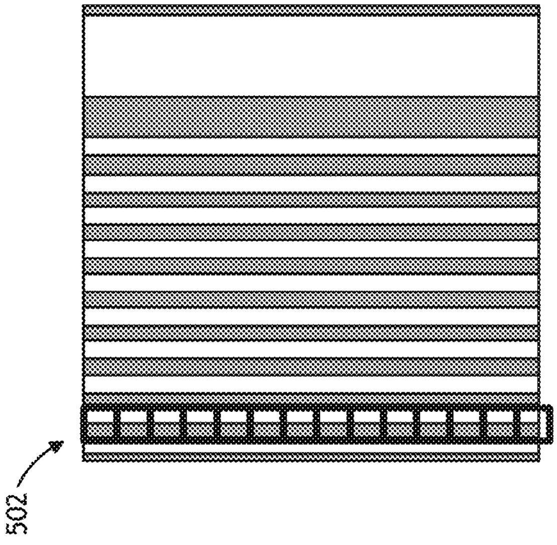

FIG.5A

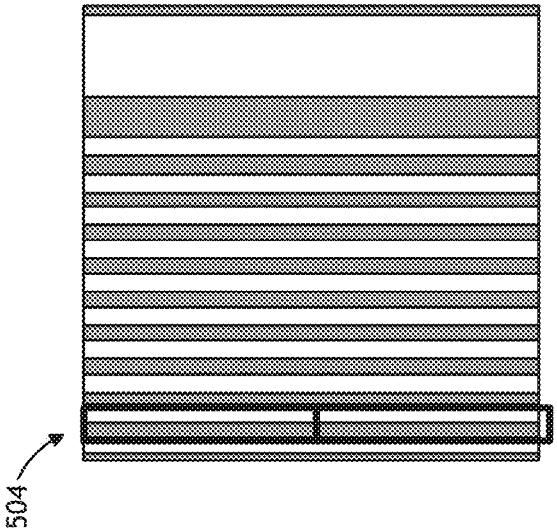

FIG.5B

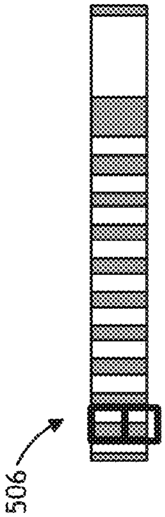

FIG.5C

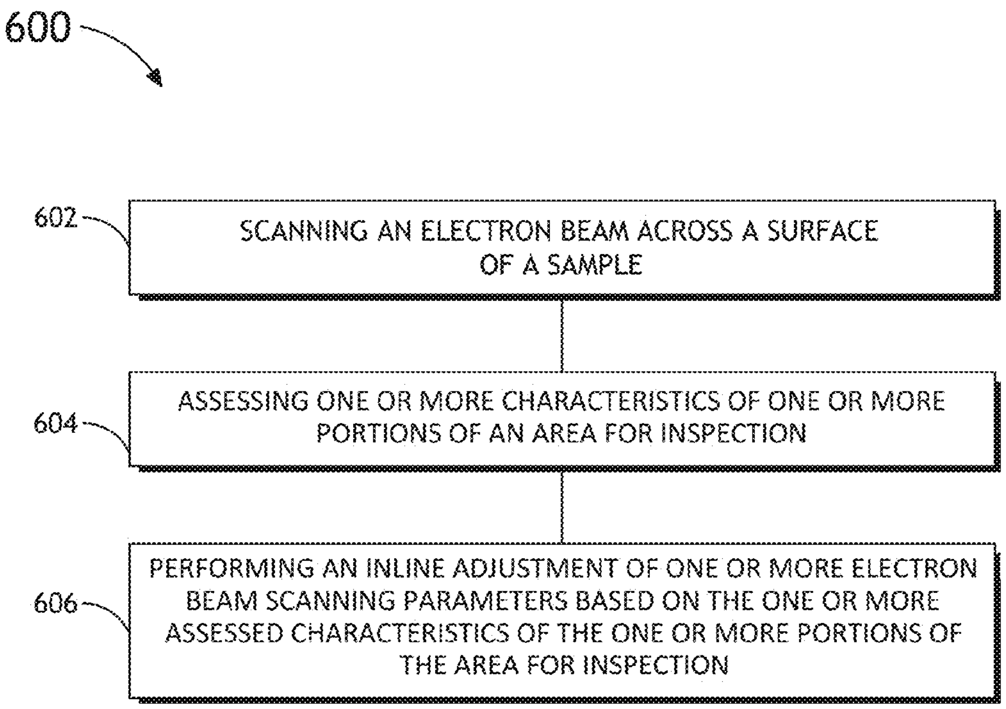
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FIG.6

# METHOD AND SYSTEM FOR ADAPTIVELY SCANNING A SAMPLE DURING ELECTRON BEAM INSPECTION

## CROSS-REFERENCE TO RELATED APPLICATION

The present application is related to and claims the benefit of the earliest available effective filing date(s) from the following listed application(s) (the "Related Applications") (e.g., claims earliest available priority dates for other than provisional patent applications or claims benefits under 35 USC §119(e) for provisional patent applications, for any and all parent, grandparent, great-grandparent, etc. applications of the Related Application(s)).

## RELATED APPLICATIONS

For purposes of the USPTO extra-statutory requirements, the present application constitutes a regular (non-provisional) patent application of United States Provisional Patent Application entitled METHODS OF IMPROVING THROUGHOUT AND SENSITIVITY OF E-BEAM INSPECTION SYSTEM, naming Gary Fan, David Chen, Vivekanand Kini and Hong Xiao as inventors, filed Apr. 27, 2013, Application Ser. No. 61/816,720.

## TECHNICAL FIELD

The present invention generally relates to electron beam sample inspection, and, in particular, to adaptively scanning a sample during electron beam inspection.

## SUMMARY

A system for adaptively scanning a sample during electron beam inspection is disclosed. In one illustrative embodiment, the system may include, but is not limited to, an inspection sub-system configured to scan an electron beam across the surface of the sample, the inspection sub-system including: an electron beam source configured to generate an electron beam, a sample stage configured to secure the sample; and a set of electron-optic elements configured to direct the electron beam onto the sample; a detector assembly including at least an electron collector, the detector configured to detect electrons from the surface of the sample; a controller communicatively coupled to one or more portions of the inspection sub-system, the controller including one or more processors configured to execute program instructions configured to cause the one or more processors to: assess one or more characteristics of one or more portions of an area for inspection; and responsive to the assessed one or more characteristics, adjust one or more scan parameters of the inspection sub-system.

A method for adaptively scanning a sample during electron beam inspection is disclosed. In one illustrative embodiment, the method may include, but is not limited to, scanning an electron beam across a surface of the sample; assessing one or more characteristics of one or more portions of an area for inspection; and performing an inline adjustment of one or more electron beam scanning parameters associated with the scanning of the electron beam across the surface of the sample based on the one or more assessed characteristics of the of one or more portions of the area for inspection.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not necessarily restrictive of the invention as claimed. The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate embodiments of the invention and together with the general description, serve to explain the principles of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

The numerous advantages of the disclosure may be better understood by those skilled in the art by reference to the accompanying figures in which:

FIG. **1** is a high level schematic illustration of a system for adaptively scanning a sample during electron beam inspection, in accordance with one embodiment of the present invention.

FIGS. **2**A-**2**E are conceptual views of a series of adaptive electron beam scanning scenarios, in accordance with embodiments of the present invention.

FIGS. **3**A-**3**B are conceptual views of a series of adaptive electron beam scanning scenarios involving the elongation of pixels along a selected direction, in accordance with embodiments of the present invention.

FIGS. **4**A-**4**B are conceptual views of a series of adaptive electron beam scanning scenarios involving the elongation of pixels along a selected direction, in accordance with embodiments of the present invention.

FIGS. **5**A-**5**C are conceptual views of a series of adaptive electron beam scanning scenarios involving the elongation of pixels along a selected direction, in accordance with embodiments of the present invention.

FIG. **6** is a process flow diagram illustrating a method for adaptively scanning a sample during electron beam inspection, in accordance with one embodiment of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

Reference will now be made in detail to the subject matter disclosed, which is illustrated in the accompanying drawings.

Referring generally to FIGS. **1** through **6**, a method and system for adaptively scanning a sample during electron beam inspection is described in accordance with the present disclosure. Embodiments of the present disclosure are directed to the adaptive scanning of a sample, such as a semiconductor wafer, during electron beam inspection. In some embodiments, one or more scan parameters associated with a given scanning scenario may be adjusted, inline, in an effort to improve one or more scanning features. In other embodiments, the inline adjustment of scan parameters may be carried out in response to one or more assessed characteristics of an area or sub-area of a sample to be inspected. These characteristics may include, but are not limited to, pattern density, pattern complexity, dominant structural orientation, defect(s) size, defect density, defect depth and defect type. In additional embodiments, the assessment of the characteristics may be carried out during inspection recipe setup, during a setup run prior to inspection or during an inspection runtime. The inline adjusted of one or more scan parameters may lead to improved inspection speed, improved inspection sensitivity, detection of multiple types of defects in a single inspection, reduced false rate, reduced nuisance rate, reduced electron dose on sample and the like.

FIG. **1** illustrates a system **100** for adaptively scanning a sample during electron beam inspection, in accordance with one embodiment of the present invention. In one embodiment, the system **100** includes an inspection sub-system **101**.

In one embodiment, the inspection sub-system **101** is an electron beam based inspection sub-system **101** suitable for scanning an electron beam **104** across a selected region of a sample **106**. In one embodiment, sample **106** includes, but is not limited to, a wafer (e.g., semiconductor wafer). In another embodiment, one or more portions of the inspection sub-system are selectably controllable in order to adaptively scan the sample **106** with an electron beam **104**. In one embodiment, one or more portions, or components, of the inspection sub-system **101** may be selectably controllable, independently or in conjunction with one or more other components, to vary, inline, one or more scan parameters of the inspection sub-system **101** based on one or more characteristics of an area (or sub-areas) of the sample **106** for inspection. For example, the one or more adjustable scan parameters of the inspection sub-system **101** include, but are not limited to, one or more electron source parameters (e.g., beam current). By way of another example, the one or more adjustable scan parameters of the inspection sub-system **101** include, but are not limited to, one or more stage parameters (e.g., stage scanning speed or sample bias voltage). By way of another example, the one or more adjustable scan parameters of the inspection sub-system **101** include, but are not limited to, one or more electron-optic parameters, such as one or more electron-optic focus parameters or one or more electron beam scanning parameters (e.g., scanning pattern, scan-line density, scan-line spacing, electron beam scanning speed, scanning range or field of scanning). By way of another example, the one or more adjustable scan parameters of the inspection sub-system **101** include, but are not limited to, one or more image forming parameters (e.g., extraction voltage, extraction field strength for secondary electrons or electron landing energy). By way of another example, the one or more adjustable scan parameters of the inspection sub-system **101** include, but are not limited to, one or more digitization parameters (e.g., digitization or pixel data rate).

In another embodiment, the one or more characteristics of the area (or sub-area) of the sample with which the scanning parameter adjustment may be based includes the complexity of one or more patterns of the sample. For example, a complexity marker (e.g., variation of line scan density) may be implemented to rank the complexity of various patterns of an area for inspection, as described further herein. In another embodiment, the one or more characteristics of the area (or sub-area) include one or more structural characteristics of one or more patterns of the sample. In another embodiment, the one or more characteristics of the area (or sub-area) include one or more defect characteristics of the sample. For example, the one or more characteristics of the area (or sub-area) may include, but are not limited to, a defect density within one or more portions of the area for inspection. By way of another example, the one or more characteristics of the area (or sub-area) may include, but are not limited to, a defect size within the one or more portions of the area for inspection. By way of another example, the one or more characteristics of the area (or sub-area) may include, but are not limited to, a defect type within the one or more portions of the area for inspection.

It is noted herein that the inspection sub-system **101** may operate in any scanning mode known in the art. For example, the inspection sub-system **101** may operate in a swathing mode when scanning an electron beam **104** across the surface of the sample **106**. In this regard, the inspection sub-system **101** may scan an electron beam **104** across the sample **106**, while the sample is moving, with the direction of scanning being nominally perpendicular to the direction of the sample motion. By way of another example, the inspection sub-system **101** may operate in a step-and-scan mode when scanning an electron beam **104** across the surface of the sample **106**. In this regard, the inspection sub-system **101** may scan an electron beam **104** across the sample **106**, which is nominally stationary when the beam **104** is being scanned.

In another embodiment, the system **100** includes a controller **102**. In one embodiment, the controller **102** is communicatively coupled to one or more portions of the inspection sub-system **101**. In one embodiment, the controller **102** is configured to assess one or more characteristics of one or more portions of an area for inspection. In one embodiment, the controller **102** may assess the one or more characteristics during inspection recipe setup, during a setup run prior to inspection or during an inspection runtime. In another embodiment, the controller **102** is configured to, in response to the assessed one or more characteristics, adjust one or more scan parameters of the inspection sub-system.

In one embodiment, the controller **102** may assess, or measure, one or more characteristics of an area (or sub-area) of the sample **106**. In one embodiment, the controller **102** may assess the complexity, or a complexity marker or metric, of one or more patterns of the sample **106**. In another embodiment, the controller **102** may assess one or more structural characteristics of one or more patterns of the sample **106**. In another embodiment, the controller **102** may assess one or more defect characteristics of the sample **106**. For example, controller **102** may assess, or measure, a defect density within one or more portions of the area for inspection. By way of another example, controller **102** may assess, or measure, a defect size within the one or more portions of the area for inspection. By way of another example, controller **102** may assess, or measure, a defect type within the one or more portions of the area for inspection

In one embodiment, the controller **102** may adjust one or more electron source parameters (e.g., beam current). In another embodiment, the controller **102** may adjust one or more stage parameters (e.g., stage scanning speed or sample bias voltage). In another embodiment, the controller **102** may adjust one or more electron-optic parameters, such as one or more electron-optic focus parameters (e.g., focus) or one or more electron beam scanning parameters (e.g., scanning pattern, scan-line density, scan-line spacing, electron beam scanning speed, scanning range or field of scanning). In another embodiment, the controller **102** may adjust one or more image forming parameters (e.g., extraction voltage, extraction field strength for secondary electrons or electron landing energy). For example, the controller **102** may vary the electron beam landing energy from one sub-area to another in order to enhance the defect signal in each sub-area or to make the defect-of-interest in each sub-area more readily detectable. By way of another example, the controller **102** may vary the extraction field or voltage controlling imaging electrons from one sub-area to another in order to enhance the defect signal in each sub-area or to make the defect-of-interest in each sub-area more readily detectable. In another embodiment, the controller **102** may adjust one or more digitization parameters (e.g., digitization or pixel data rate).

In one embodiment, the inspection sub-system **101** includes an electron beam source **120** for generating one or more electron beams **104**. The electron beam source **120** may include any electron source known in the art. For example, the electron beam source **120** may include, but is not limited to, one or more electron guns. In one embodiment, the controller **102** is communicatively coupled to the electron source **120**. In another embodiment, the controller **102** may adjust one or more electron source parameters via a control signal to the electron source **120**. In another embodiment, the controller **102** may adjust one or more one or more electron source parameters in response to the one or more assessed characteristics of the area of the sample for inspection. For example, the controller **102** may vary the beam current for the electron beam **104** emitted by source **120** via a control signal transmitted to control circuitry of the electron beam source **120**.

In another embodiment, the sample **106** is disposed on a sample stage **108** suitable for securing the sample **106** during scanning. In another embodiment, the sample stage **108** is an actuatable stage. For example, the sample stage **108** may include, but is not limited to, one or more translational stages suitable for selectably translating the sample **106** along one or more linear directions (e.g., x-direction, y-direction and/or z-direction). By way of another example, the sample stage **108** may include, but is not limited to, one or more rotational stages suitable for selectably rotating the sample **106** along a rotational direction. By way of another example, the sample stage **108** may include, but is not limited to, a rotational stage and a translational stage suitable for selectably translating the sample along a linear direction and/or rotating the sample **106** along a rotational direction.

In one embodiment, the controller **102** is communicatively coupled to the sample stage **108**. In another embodiment, the controller **102** may adjust one or more stage parameters via a control signal transmitted to the sample stage **108**. In another embodiment, the controller **102** may adjust one or more one or more stage parameters in response to the one or more assessed characteristics of the area of the sample for inspection. For example, the controller **102** may vary the sample scanning speed via a control signal transmitted to control circuitry of the sample stage **108**. For instance, the controller **102** may vary the speed with which sample **106** is linearly translated (e.g., x-direction or y-direction) relative to the electron beam **104**.

In another embodiment, the inspection sub-system **101** includes a set of electron-optic elements **103**. The set of electron-optics may include any electron-optic elements known in the art suitable for focusing and/or directing the electron beam **104** onto a selected portion of the sample **106**. In one embodiment, the set of electron-optics elements includes one or more electron-optic lenses. For example, the electron-optic lenses may include, but are not limited to, one or more condenser lenses **112** for collecting electrons from the electron beam source. By way of another example, the electron-optic lenses may include, but are not limited to, one or more objective lenses **114** for focusing the electron beam onto a selected region of the sample **106**.

In another embodiment, the set of electron-optics elements includes one or more electron beam scanning elements. For example, the one or more electron beam scanning elements **111** may include, but are not limited to, one or more scanning coils or deflectors suitable for controlling a position of the beam relative to the surface of the sample **106**. In this regard, the one or more scanning elements **111** may be utilized to scan the electron beam **104** across the sample **106** in a selected pattern.

In one embodiment, the controller **102** is communicatively coupled to the set of electron-optic elements **103**. In another embodiment, the controller **102** may adjust one or more electron-optic parameters via a control signal transmitted to one or more of the set of electron-optic elements **103**. In another embodiment, the controller **102** may adjust one or more electron-optic parameters in response to the one or more assessed characteristics of the area of the sample for inspection.

In one embodiment, the controller **102** is communicatively coupled to the one or more electron-optic lenses **112**, **114** of the set of electron-optic elements **103** and is configured to control one or more electron-optic focus parameters (e.g., electron-optic focus). For example, the controller **102** may vary the focus of electron beam **104** via a control signal transmitted to electron-optic lenses **112** or **114**. In another embodiment, the controller **102** is communicatively coupled to the one or more electron beam scanning elements **111** of the set of electron-optic elements **103** and is configured to control one or more electron beam scanning parameters. For example, the controller **102** may vary the electron beam scan speed, scan range, field of scanning, scan-line density or line spacing via one or more control signals transmitted to the electron beam scanning elements **111**.

In another embodiment, the inspection sub-system includes a detector assembly **118**. In another embodiment, the controller **102** may adjust one or more digitization parameters via a control signal transmitted to one or more portions of the detector assembly **118**. In another embodiment, the controller **102** may adjust one or more digitization parameters in response to the one or more assessed characteristics of the area of the sample for inspection.

In one embodiment, the detector assembly **118** includes an electron collector **117** (e.g., secondary electron collector). In another embodiment, the detector assembly **118** includes a detector **119** (e.g., scintillating element and PMT detector **119**) for detecting electrons from the sample surface (e.g., secondary electrons). In another embodiment, the controller **102** is communicatively coupled to the electron collector **117**. In one embodiment, the controller **102** may adjust one or more image forming parameters via a control signal transmitted to the collector **117**. In one embodiment, the controller **102** may adjust the extraction voltage or the extraction field strength for the secondary electrons. For example, the controller **102** may vary the electron beam landing energy from one sub-area to another in order to enhance the defect signal in each sub-area or to make the defect-of-interest in each sub-area more readily detectable. In another embodiment, the controller **102** may adjust the electron landing energy on the sample **106**. For example, the controller **102** may vary the extraction field or voltage controlling imaging electrons from one sub-area to another in order to enhance the defect signal in each sub-area or to make the defect-of-interest in each sub-area more readily detectable. In another embodiment, the controller **102** may adjust the sample bias voltage.

While the foregoing description focused on the detector assembly **118** in the context of the collection of secondary electrons, this should not be interpreted as a limitation on the present invention. It is recognized herein that the detector assembly **118** may include any device or combination of devices known in the art for characterizing a sample surface or bulk with an electron beam **104**. For example, the detector assembly **118** may include any particle detector known in the art configured to collect backscattered electrons, Auger electrons, transmitted electrons or photons (e.g., x-rays emitted by surface in response to incident electrons).

In another embodiment, the controller **102** is communicatively coupled to the detector **119** of the detector assembly **118**. In one embodiment, the controller **102** may adjust one or more digitization parameters via a control signal transmitted to the detector **119**. For example, the controller **102** may adjust the digitization or pixel data rate of the detector **119** via a control signal transmitted to the detector **119**.

In another embodiment, the detector of the detector assembly **118** includes a light detector. For example, the anode of a PMT detector of the detector **119** may consist of a phosphor anode, which is energized by the cascaded electrons of the PMT detector absorbed by the anode and subsequently emits light. In turn, the light detector may collect light emitted by the phosphor anode in order to image the sample **106**. The light detector may include any light detector known in the art, such as, but not limited to, a CCD detector or a CCD-TDI detector.

FIGS. **2**A-**2**E illustrate a series of conceptual views of implementations of system **100** and/or method **600**, in accordance with the present disclosure. FIGS. **2**A and **2**B illustrate the varying of scan-line density in accordance with the local pattern complexity of the sample **106**, in accordance with one or more embodiments of the present invention. In one embodiment, the system **100** may utilize equally space scan patterns, as shown by **202** and **204**. As shown in FIG. **2**A, in cases where areas between repeating sample patterns **200** are of no interest, the system **100** may skip these middling areas when scanning. A scanned image of this configuration is depicted in **206**. As shown in FIG. **2**B, in cases where the areas between the patterns **200** are of interest, but a factor exists allowing for sparser sampling between the patterns **200**, the system **100** may apply a modified scanning pattern **204** when scanning these areas. For example, a modified scanning pattern, such as that shown in **204**, may be implemented when the defect sizes in these areas are expected to be larger. A scanned image of this configuration is depicted in **208**.

FIGS. **2**C and **2**D illustrate the varying of scan-line density in accordance with the pattern complexity of the sample **106**, in accordance with one or more embodiments of the present invention. In one embodiment, the system **100** may utilize variably-spaced scan patterns, as shown by **212** and **214**. As shown in FIG. **2**C, in cases where areas between repeating sample patterns **210** are of no interest, the system **100** may skip these middling areas when scanning. A scanned image of this configuration is depicted in **216**. As shown in FIG. **2**D, in cases where the areas between the patterns **210** are of interest, but a factor exists allowing for sparser sampling between the patterns **210**, the system **100** may apply a modified scanning pattern **214** when scanning these areas. For example, a modified scanning pattern, such as that shown in **214**, may be implemented when the defect sizes in these areas are expected to be larger. A scanned image of this configuration is depicted in **218**.

FIG. **2**E illustrates the varying of scan pattern and/or imaging parameters implemented by system **100** and/or method **600**, in accordance with one or more embodiments of the present invention. In one embodiment, the scan pattern and/or imaging parameters varied by the system **100** may include, but are not limited to, electron landing energy on the sample, extraction field for imaging electrons and the like. In another embodiment, the scan pattern and/or imaging parameters may be varied by the system **100** in order to enhance defect signal levels or otherwise make one or more defects of interest more readily detectable for each sub-area. As a result, different type of defects of interest, which may be region-specific, may be contrast-enhanced and captured during the same inspection. For example, **220** of FIG. **2**E depicts a repeating pattern **220**, which each may include two or more regions, each region with a different defects type. Scanning pattern **222** may be utilized to scan such a repeating pattern, where the imaging parameters are changed dynamically for the purposes of detecting two or more defect types in different regions in one inspection. Image **224** depicts a result image captured with system **100**, which depicts region-specific contrast enhancement.

FIGS. **3**A-**3**B illustrate a series of conceptual views of elongation of pixels implemented with system **100** and/or method **600**, in accordance with the present disclosure. In one embodiment, the controller **102** may elongate one or more pixels along a selected direction.

In one embodiment, as shown in image **300** and **302** of FIG. **3**A, the controller **102** may elongate one or more pixels along an electron beam scan direction by increasing beam scan range by a selected factor E (e.g., E=1-10) and maintaining stage speed and pixel data rate. It is noted that this elongation may lead to rectangular-shaped pixels as depicted in image **302**. In another embodiment, the controller **102** may elongate one or more pixels along an electron beam scan direction by increasing scan voltage by a select factor E.

It is noted herein that for certain sample layer geometries, the foregoing approach may significantly speed up inspection without a significant loss of inspection sensitivity. In this regard, an effectively rectangular beam shape may be achieved. It is further noted that in cases where the beam scan direction is along one or more structure lines, as shown in image **302**, an improved signal to noise ratio may be achieved as the beam shape matches the pixel shape. In cases where the beam scan direction is perpendicular (or non-parallel in general), as shown in images **304** and **306**, a significant under-sampling is achieved.

In another embodiment, as shown in images **310** and **312** of FIG. **3**B, the controller **102** may elongate one or more pixels along a direction perpendicular to an electron beam scan direction by increasing stage speed by a selected factor E and maintaining beam scan range and pixel data rate. In this regard, the square pixels of image **310** become rectangular pixels as shown in **312**. In cases where the beam scan direction is along one or more structure lines, as shown in images **314** and **316**, a significant under-sampling is achieved.

FIGS. **4**A-**4**B illustrate a series of conceptual views of the elongation of pixels utilizing system **100** and/or method **600**, in accordance with the present disclosure. It is noted herein that previous scanning methods failed to scan all areas of a sample effectively and risk missing a catastrophic defect. Further, electron beam inspection with adaptive scanning capabilities in the slow scanning direction is not particularly useful for voltage contrast (VC) defect inspection.

In another embodiment, the controller **102** may elongate one or more pixels along the fast electron beam scan direction by increasing scan voltage by a select factor E. It is noted herein that increasing the scanning voltage by a factor E allows the system **100** to increase the deflection of electrons relative to the normal (non-scaled voltage) proportionally to the factor E. In another embodiment, the pixel number of the swath width may be reduced (e.g., 256 pixels wide), allowing the factor E to be increased dramatically (e.g., E>10).

It is noted herein that such a capability provides significant throughput improvement. It is recognized that such an approach is particularly useful in detecting VC defects in straight conductive lines. For example, as shown in image **402** of FIG. **4**A, a square non-elongated pixel **404** is depicted. As shown in image **406** of FIG. **4**B, an elongated pixel **408** may be created by the controller **102** by increasing scan voltage by a select factor E. In the example depicted in FIG. **4**B, the factor corresponds to E=7. In one embodiment, the system **100** may carry out a fast scan along a conductive line, with an elongating factor E, which may charge the conductive line and capture VC variations caused by electrical defects (e.g., broken lines, short between lines and non-opened contact plugs causing an open circuit of the conductive lines to ground). It is noted herein that the above values for the elongating factor E are not limiting and should be interpreted merely as illustrative. For example, the elongating factor may be in the range of 1-10 and further in the range 10-100.

FIGS. **5**A-**5**C illustrate a series of conceptual views of the elongation of pixels utilizing system **100** and/or method **600**, in accordance with the present disclosure. FIG. **5**A depicts a conceptual view of a SEM image **502** captured with a normal square pixel scan. Image **504** of FIG. **5**B depicts a conceptual view of an elongated pixel having E=7. FIG. **5**C depicts a conceptual view of a SEM image **502** captured with an elongated pixel with E=7.

In one embodiment, the controller **102** includes one or more processors (not shown) configured to execute program instructions suitable for causing the one or more processors to execute one or more steps described in the present disclosure. In one embodiment, the one or more processors of the controller **102** may be in communication with a carrier medium (e.g., non-transitory storage medium (i.e., memory medium)) containing the program instructions configured to cause the one or more processors of the controller **102** to carry out the various steps described through the present disclosure. It should be recognized that the various steps described throughout the present disclosure may be carried out by a single computing system or, alternatively, a multiple computing system. The controller **102** may include, but is not limited to, a personal computer system, mainframe computer system, workstation, image computer, parallel processor, or any other device known in the art. In general, the term "computer system" may be broadly defined to encompass any device having one or more processors, which execute instructions from a memory medium. Moreover, different subsystems of the system **100** may include a computer system or logic elements suitable for carrying out at least a portion of the steps described above. Therefore, the above description should not be interpreted as a limitation on the present invention but merely an illustration.

The controller **102** may be communicatively coupled to one or more portions of the inspection sub-system **101** via any transmission medium known in the art. For example, the controller **102** may be communicatively coupled to one or more portions of the inspection sub-system **101** via a wireline transmission link or a wireless transmission link. In this manner, the transmission medium may serve as a data link between the controller **102** and other subsystems of the system **100**.

The embodiments of the system **100** illustrated in FIG. **1**A may be further configured as described herein. In addition, the system **100** may be configured to perform any other step(s) of any of the method embodiment(s) described herein.

FIG. **6** is a flow diagram illustrating steps performed in a method for adaptively scanning a sample during electron beam inspection. It is recognized that steps of the process flow **600** may be carried out via pre-programmed instructions executed by one or more processors of controller **102**. It should, however, be recognized by those skilled in the art, that the system **100** should not be interpreted as a limitation on process **600** as it is contemplated that a variety of system configurations may carry out process flow **600**.

In a first step **602**, an electron beam across a surface of the sample. For example, as shown in FIG. **1**A, an electron beam **104** may be scanned in accordance with a swath mode inspection procedure or a step-and-scan mode inspection procedure. For instance, one or more scanning elements **111** and/or stage **108** may be utilized to translate the electron beam **104** along a selected pattern across the surface of the sample **106**.

In a second step **604**, one or more characteristics of one or more portions of an area (or sub-area) for inspection are assessed. For example, the controller **102** may assess (or determine or measure) one or more characteristics of one or more portions of an area (or sub-area) for inspection. For instance, the controller **102** may analyze pattern data acquired by detector assembly **118** associated with the area (or sub-area) for inspection. In another instance, the controller **102** may analyze predicted pattern data based on one or more anticipated device features (e.g., repeating structures and etc.).

In a third step **606**, an inline adjustment of one or more scan parameters associated with the scanning of the electron beam across the surface of the sample is performed based on the one or more assessed characteristics of the of one or more portions of the area for inspection. For example, the controller **102** may perform an inline adjustment of one or more scan parameters associated with the scanning of the electron beam across the surface of the sample based on the one or more assessed characteristics of the of one or more portions of the area for inspection.

All of the methods described herein may include storing results of one or more steps of the method embodiments in a storage medium. The results may include any of the results described herein and may be stored in any manner known in the art. The storage medium may include any storage medium described herein or any other suitable storage medium known in the art. After the results have been stored, the results can be accessed in the storage medium and used by any of the method or system embodiments described herein, formatted for display to a user, used by another software module, method, or system, etc. Furthermore, the results may be stored "permanently," "semi-permanently," temporarily, or for some period of time. For example, the storage medium may be random access memory (RAM), and the results may not necessarily persist indefinitely in the storage medium.

It is further contemplated that each of the embodiments of the method described above may include any other step(s) of any other method(s) described herein. In addition, each of the embodiments of the method described above may be performed by any of the systems described herein.

Those having skill in the art will recognize that the state of the art has progressed to the point where there is little distinction left between hardware and software implementations of aspects of systems; the use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software can become significant) a design choice representing cost vs. efficiency tradeoffs. Those having skill in the art will appreciate that there are various vehicles by which processes and/or systems and/or other technologies described herein can be effected (e.g., hardware, software, and/or firmware), and that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle; alternatively, if flexibility is paramount, the implementer may opt for a mainly software implementation; or, yet again alternatively, the implementer may opt for some combination of hardware, software, and/or firmware. Hence, there are several possible vehicles by which the processes and/or devices and/or other technologies described herein may be effected, none of which is inherently superior to the other in that any vehicle to be utilized is a choice dependent upon the context in which the vehicle will be deployed and the specific concerns (e.g., speed, flexibility, or predictability) of the implementer, any of which may vary. Those skilled in the art will recognize that optical aspects of implementations will typically employ optically-oriented hardware, software, and or firmware.

Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein can be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system generally includes one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

It is believed that the present disclosure and many of its attendant advantages will be understood by the foregoing description, and it will be apparent that various changes may be made in the form, construction and arrangement of the components without departing from the disclosed subject matter or without sacrificing all of its material advantages. The form described is merely explanatory, and it is the intention of the following claims to encompass and include such changes.

What is claimed:

**1**. A system for adaptively scanning a sample during electron beam inspection comprising:

an inspection sub-system configured to scan an electron beam across the surface of the sample, the inspection sub-system including:

an electron beam source configured to generate an electron beam,

a sample stage configured to secure the sample;

a set of electron-optic elements configured to direct the electron beam onto the sample; and

a detector assembly including at least an electron collector, the detector configured to detect electrons from the surface of the sample; and

a controller communicatively coupled to one or more portions of the inspection sub-system, the controller including one or more processors configured to execute program instructions configured to cause the one or more processors to:

assess at least one of a pattern characteristic or a defect characteristic of one or more portions of an area for inspection; and

responsive to at least one of the assessed pattern characteristic or the defect characteristic, adjust one or more scan parameters of the inspection sub-system.

**2**. The system of claim **1**, wherein the inspection sub-system is configured to scan an electron beam across the surface of one or more wafers.

**3**. The system of claim **1**, wherein the electron beam source includes one or more electron guns.

**4**. The system of claim **1**, wherein the sample stage comprises:

at least one of a linear sample stage and a rotational sample stage.

**5**. The system of claim **1**, wherein the one or more scanning parameters adjusted by the controller comprise:

at least one of one or more stage parameters, one or more electron optic parameters, one or more electron beam scanning parameters, one or more image forming parameters and one or more digitization parameters.

**6**. The system of claim **1**, wherein the pattern characteristic of one or more portions of an area for inspection comprises:

a complexity metric of one or more patterns within the one or more portions of the area for inspection.

**7**. The system of claim **1**, wherein the pattern characteristic of one or more portions of an area for inspection comprises:

a structural characteristic of one or more patterns within the one or more portions of the area for inspection.

**8**. The system of claim **1**, wherein the defect characteristic of one or more portions of an area for inspection comprises:

a defect density within the one or more portions of the area for inspection.

**9**. The system of claim **1**, wherein the defect characteristic of one or more portions of an area for inspection comprises:

a defect size within the one or more portions of the area for inspection.

**10**. The system of claim **1**, wherein the defect characteristic of one or more portions of an area for inspection comprises:

a defect type within the one or more portions of the area for inspection.

**11**. The system of claim **1**, wherein the controller is configured to assess at least one of a pattern characteristic or a defect characteristic of one or more portions of an area for inspection during an inspection recipe setup.

**12**. The system of claim **1**, wherein the controller is configured to assess at least one of a pattern characteristic or a defect characteristic of one or more portions of an area for inspection during a setup inspection run prior to inspection.

**13**. The system of claim **1**, wherein the controller is configured to assess at least one of a pattern characteristic or a defect characteristic of one or more portions of an area for inspection during inspection runtime.

**14**. The system of claim **1**, wherein the controller is communicatively coupled to the electron source and is configured to control one or more electron source parameters.

**15**. The system of claim **1**, wherein the controller is communicatively coupled to the sample stage and is configured to control one or more stage parameters of the sample disposed on the sample stage.

**16**. The system of claim **1**, wherein the controller is communicatively coupled to one or more electron-optic elements of the set of electron-optic elements and is configured to control one or more electron-optic parameters.

**17**. The system of claim **1**, wherein the set of electron-optic elements includes one or more electron optic lenses for focusing the electron beam onto the surface of the sample.

**18**. The system of claim **17**, wherein the controller is communicatively coupled to the one or more electron-optic lenses of the set of electron-optic elements and is configured to control one or more electron-optic focus parameters.

**19**. The system of claim **1**, wherein the set of electron-optic elements includes one or more electron beam scanning elements configured to scan the electron beam across the surface of the sample.

**20**. The system of claim **19**, wherein the controller is communicatively coupled to the one or more electron beam scanning elements and is configured to control one or more electron beam scanning parameters with the electron beam scanning coils.

**21**. The system of claim **1**, wherein the controller is communicatively coupled to a portion of the detector assembly.

**22**. The system of claim **21** wherein the controller is communicatively coupled to the electron collector of the detector assembly and is configured to control one or more image forming parameters.

**23**. The system of claim **1**, wherein the controller is communicatively coupled to the detector assembly and is configured to control at least one digitization parameter of the detector assembly.

**24**. The system of claim **1**, wherein the detector assembly further includes a scintillating element and a photomultiplier tube.

**25**. The system of claim **24**, wherein the detector assembly further includes a light detector.

**26**. The system of claim **1**, wherein the controller is configured to elongate one or more pixels along a selected direction.

**27**. The system of claim **26**, wherein the controller is configured to elongate one or more pixels along an electron beam scan direction by increasing beam scan range by a selected factor and maintaining stage speed and pixel data rate.

**28**. The system of claim **26**, wherein the controller is configured to elongate one or more pixels along an electron beam scan direction by increasing scan voltage by a selected factor.

**29**. The system of claim **28**, wherein the controller is configured to elongate one or more pixels along a fast scan direction by increasing scan voltage by a selected factor.

**30**. The system of claim **29**, wherein the controller is configured to elongate one or more pixels along a fast scan direction by increasing scan voltage by a selected factor in order to detect one or more voltage contrast defects of a conductive line of the sample.

**31**. The system of claim **26**, wherein the controller is configured to elongate one or more pixels along a direction perpendicular to an electron beam scan direction by increasing stage speed by a selected factor and maintaining beam scan range and pixel data rate.

**32**. A method for adaptively scanning a sample during electron beam inspection comprising:

scanning an electron beam across a surface of the sample;

assessing at least one of a pattern characteristic or a defect characteristic of one or more portions of an area for inspection; and

performing an inline adjustment of one or more scan parameters associated with the scanning of the electron beam across the surface of the sample based on at least one of the assessed pattern characteristic or the defect characteristic of the of one or more portions of the area for inspection.

**33**. The method of claim **32**, wherein the scanning an electron beam across a surface of the sample comprises:

scanning an electron beam across a surface of the sample in a swathing inspection mode.

**34**. The method of claim **32**, wherein the scanning an electron beam across a surface of the sample comprises:

scanning an electron beam across a surface of the sample in a step-and-scan inspection mode.

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